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Water Contamination and Disinfection: A Review

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Abstract Worldwide, one of the biggest concerns for water quality is the contamination of water resources by water-borne pathogens and the diseases that result from it. An increasing number of recent publications attest to the need for studies that synthesize knowledge from multiple fields, covering comparative aspects of pathogen contamination and unify them in one place in order to present and address the problem as a whole. These publications also demonstrate the growing interest in controlling water-borne pathogens in water resources. Contamination arises from pathogens (bacteria, viruses, parasites), organic and inorganic pollutants and environmental factors. Additional transdisciplinary studies are clearly needed in order to fully understand the situation. These studies should integrate knowledge from multi-research endeavors addressing pathogen contamination and provide a thorough overview. As a result, the objective of this review is to provide a comprehensive evaluation of the research spectrum regarding pathogen contamination of water resources and the difficulties that accompany it. The contaminants in water disrupt the mechanism spontaneity and cause short and long-term waterborne diseases. In this review, we will focus on the probable microbial and parasitic contaminations which affect water quality and health also, to preventing waterborne diseases.

Key Words Microbial, Disinfection, parasites, contamination, waterborne diseases

INTRODUCTION

Potable water is essential for all standard household activities. Waterborne diseases pose a significant threat to human health. Measures to enhance drinking water quality yield substantial health advantages. including consumption, culinary preparation and personal sanitation. The characteristics and regulations of drinking-water standards may differ among countries and regions. The lack of water on a global scale poses a serious threat to both the Sustainable Development Goals and ongoing human advancement. For example, agricultural commodities (which account for the majority of the world's water usage) are frequently sold and eaten outside of their production regions. Due to these commercial ties, variations in worldwide demand have an effect on regional water systems. Similar to this, shocks to a local water system can spread around the world. Changes in the regional water supply or sectoral demand can spread across sectors and scales since water is a vital input to other industries, including manufacturing, transportation and energy [1]. A couple of the most significant biophysical elements influencing food production are water. Water is still a crucial component that limits the amount of food produced worldwide, even if technological advancements have made it possible for humans to economically manufacture enormous amounts of nitrogen fertilizers [2]. There is a severe shortage of freshwater resources in the Middle East and the water industry is particularly vulnerable to climate change. Water shortages are a recurring problem in the Kingdom of Saudi Arabia, which is among the driest places on earth and they require prompt response. In terms of public health, the Kingdom also faces an increasing risk for several reasons, including the rapid deterioration of water quality [3]. Water is an essential resource for all living organisms on the planet. For nearly every living creature on the planet, water is an essential resource. Water is essential for the survival of most living things, including humans. When water becomes contaminated, physically, chemically, biologically, or radiologically, it has an adverse effect on life. Water contamination has long been a problem in human history. The Sushruta, an Indian Sanskrit text, discusses infections

comparable to cholera that were spread by water as early as 500-400 B.C. [4]. Although cholera infections have not been reported in wealthier nations recently, mostly due to improved sanitation, millions of people still get Vibrio cholera every year in destitute nations. According to WHO estimates, cholera causes between 10,000 and 120,000 deaths annually, the majority of which occur in developing countries and account for 3-5 million cases of the disease. Over the years, cholera has claimed millions of lives in both developed and poor countries [4,5].

Recent statistics provided on overview of water contaminations according to Unicef: Approximately 2 billion people (26% of the global population) lack access to safe drinking water, while 3.6 billion people (46%) do not have safely managed sanitation services. According to Uncif 2016. Additionally studies concluded that, the number of significant cities confronting water scarcity under at least one scenario was expected to rise from 193 (37%) to 292 (56%). The data recorded the escalating issues of water contamination and the pressing necessity for enhanced disinfection technologies, more stringent controls on pollutants such as PFAS and sustainable global water management practices [6].

Water contamination presents a substantial global public health issue, originating from pathogenic microorganisms (bacteria, viruses and protozoa). Polluted water leads to the proliferation of waterborne diseases including cholera, typhoid and dysentery, especially in areas lacking sufficient sanitation and water treatment facilities [7]. Polluted water leads to the proliferation of waterborne diseases including cholera, typhoid and dysentery, especially in areas lacking sufficient sanitation and water treatment facilities [7]. This will be solved by eradicate detrimental organisms, such as bacteria, viruses and protozoa, to mitigate the danger of waterborne illnesses. natural organic debris. Chemical contaminants also a problem. This pollutants may stem from human waste, industrial effluents, agricultural runoff, or environmental occurrences such as flooding, reduce these chemical and physical pollutants to comply with water quality regulations [8]. Chemical disinfectants such as chlorine interact with natural organic matter to generate Disinfection By-Products (e.g., trihalomethanes), which may provide long-term health hazards, including cancer [9]. Disinfection is an essential procedure for guaranteeing water safety by inactivating or eliminating dangerous bacteria [10]. The variability in raw water quality, such as the presence of humic compounds or ammonia, necessitates elevated disinfectant doses to get efficient microbial reduction. Access and Sustainability: In low and middle-income areas, insufficient access to modern disinfection methods heightens the danger of disease epidemics. This twin challenge achieving efficient pathogen elimination while mitigating dangers associated with disinfection byproducts-necessitates refined disinfection procedures customized to local water quality parameters and resource accessibility [8]. Implement modern technology or pre-treatment methods to reduce the development of disinfection byproducts (DBPs) [11]. Design economical and scalable disinfection methods appropriate for resource-constrained areas. Promote multi-barrier strategies to successfully tackle various sources of pollution [12].

Risks of pathogenic bacteria in water

According to the World Health Organization (WHO), 3.4 million people die from Water resources contaminated by harmful microbes. Worldwide, one of the biggest concerns for water quality is the contamination of water resources by water-borne pathogens and the diseases that result from it. A wider understanding of pathogen contamination in freshwater (rivers, lakes, reservoirs, groundwater) and salt (estuaries and coastal seas) resources is made possible by the growing interest in managing waterborne infections in water resources [7].

Water-related illnesses each year, with children making up the majority of these deaths (WHO 2014). According to a 2014 assessment conducted by UNICEF, 4000 children perish each day as a result of drinking contaminated water. The WHO (2010) estimates that over 2.6 billion people lack access to safe water, which results in over 2.2 million annual deaths-1.4 million of which are in children. Improved water quality can reduce the worldwide sickness burden by around 4% (WHO 2010). Although diseases linked to water are widespread in developing countries, they equally seriously threaten wealthier countries [13]. Arnone and Walling compiled data on epidemics that happened in the US between 1986 and 2000 for a 2007 study [14] found that 95 outbreaks and 5,905 cases were connected to recreational water.

Drinking water contaminated by microorganisms can lead to illness; annually, 485,000 people are thought to die as a result of drinking biologically contaminated water [15]. It is usual for every household in Europe and North America to have a reliable and purified water supply, the situation is quite different in developing nations prevalence of waterborne illnesses. Approximately 2.5 billion individuals lack access to enhanced sanitation facilities, resulting in over 1.5 million child diseased annually due to diarrheal illnesses [16]. According to the World Health Organization (WHO), the annual mortality rate of waterborne illnesses exceed 5 million individuals. Over 50% are microbial diseases of the intestines, with cholera being the most prominent [17]. Water is necessary for life, but many people lack access to clean and safe drinking and kitchen tap water and many dies as a result of bacterial diseases contracted through the water [7]. These illnesses are caused by the presence of harmful bacteria in untreated water, such as Vibrio cholera, *Escherichia coli* and *Enterococci* spp. (Including *Enterococcus faecalis*), behind numerous epidemics [18]. In poor countries such as those in Africa, millions of people suffer from water-borne ailments [17]. A variety of different microbes and germs have

been linked to about 29.53% of cases of gastrointestinal illnesses (GI) [19], which can cause symptoms like vomiting, diarrhea nausea, fever and stomach pain. several cases were caused by Shigella species [20]. Moreover, 10.99, 10.08 and 6.59% of the cases were caused by Adenoviruses, Leptospira and *Cryptosporidium parvum*, respectively. About 23 and 21% of the epidemics were caused by GI and Shigella species, respectively. In addition, 16.84, 12.63 and 7.37% of the outbreaks were caused by Naegleria fowleri, *E. coli* 0157:H7 and *Schistosoma* spp. [21]. There is various causes for Presence of Pathogenic Bacteria in Water, including contamination from human or animal waste, insufficient water sanitation systems and anthropogenic activities that introduce bacteria into water resources. It highlights the spread of harmful microorganisms like *E. coli*, Shigella and Vibrio cholera [7].

The main sources of fecal microbes, including pathogens, are wastewater discharges in freshwaters and coastal seawaters [7]. Pathogenic bacterial strains such as *Shigella B. cereus*, *Staph aureus*, Listeria and *Escherichia coli* are common pathogens in water, however, these are normally detected in little concentrations. Listeria are the most common pathogens found. It has never been possible to isolate Salmonella. The presence of pathogens is frequently accompanied by traditional contamination markers such as *E. coli*, enterococci and other aerobic bacteria [22].

Antibiotic resistance bacterial strains very dangerous if it found in water. These types of bacteria produce many pathogens because of their antimicrobial resistance patterns. The resistance genes in most genera of these bacterial strains are coded in plasmids [23]. Antibiotics are arguably the most successful form of chemotherapy developed and save in numerous human lives every day. The emergence of antibiotic-resistant bacteria limits the clinical use of antibiotics and, as resistant bacteria become more prevalent, there is increasing concern that existing antibiotics will become in-effective against these pathogens and more expensive [17].

Water Pollution by Parasites and some removal used methods

The main cause of waterborne and water-washed diseases is fecal material in the water supply and lack of hygiene. The most frequent etiological causes of the mortality among children in recent years by Protozoan parasites. Globally they are responsible for 1.7 billion cases of diarrhea, which leads to 842,000 deaths per year [24,25]. The transmission of Cryptosporidium and Giardia is fecal-oral were transmitted and Infection occurs through drinking water or swallowing water while swimming in open pools. In developed countries the majority of laboratory-confirmed cases by parasites in drinking water and also, in the USA, 411,041 cases of outbreaks caused by Cryptosporidium and Giardia associated with drinking water were registered for 1990-2012 (Waterborne Disease and Outbreak 2017). Omarova *et al.* [26] on their findings of Giardia and Cryptosporidium parasites in drinking water and wastewater treatment methods, they found that these two kinds of parasites are identified during waterborne or water-washed outbreaks and they are less sensitive than most of the bacteria and viruses to conventional drinking water and wastewater treatment methods [26].

Major etiological agents such Giarida, Cryptosporidium, *E. coli* cholera and Salmonella were responsible for several outbreaks in addition to acute gastroenteritis [18,27]. Approximately 95.89% of the 437,082 cases and 48 outbreaks that occurred during that time were brought on by tainted drinking water, specifically *Cryptosporidium parvum*. *Giardia lamblia* caused around 42% of the outbreaks, while GI was responsible for about 31% of them. Craun *et al.* [18] reported statistics on water-borne outbreaks in the United States and discovered that between 1920 and 2002, there were at least 1870 occurrences (or 23 per year). In addition to acute gastroenteritis, major etiological agents like Salmonella, *E. coli*, Giarida, Cryptosporadium and *V. cholera* were the cause of multiple outbreaks [18]. Forty eight outbreaks and 437,082 cases that took place during that period were caused by polluted drinking water, specifically *Cryptosporidium parvum*, accounting for approximately 95.89% of the cases. Roughly 42% of the outbreaks were caused by *Giardia lamblia* and roughly 31% were caused by GI. According to data on water-borne epidemics in the US published in 2006 by Craun *et al.* [18], there were at least 1870 occurrences, or 23 per year, between 1920 and 2002 [18,28]. The claimed prevalence of illnesses connected with these outbreaks is likely underestimated due to insufficient exposure data and unreported cases [18]. The removal efficiency of these parasites from water is important for cleaning water. According to different literatures, the most common treatment efficiencies were filtration which is effective in reducing the concentration of parasites especially Giardia cysts than other conventional filtrations or granulated media [29]. Removing parasites by coagulation, flocculation and settling were used to separate solids from the liquid phase under gravity [30]. Pressure-actuated membrane processes such as microfiltration, ultrafiltration, nanofiltration and reverse osmosiswere also used in the USA and Europe [29,31,32]. Disinfectant for drinking water treatment by chlorine is the most commonly used method in many developed and developing countries [31]. Ozone is used as a toxic for some protozoan cysts such as Cryptosporidium and other water pathogens, also improve water taste and color, as well as to remove organic and inorganic compounds in water [32]. The UV radiation found to be effective for removing pathogenic microbed from water [26].

Recommendations to avoid water contamination with pathogenic bacteria

The increasing awareness of key pathogen sources and their substantial effects on water resources is essential, as the

prevalence of pathogen contamination around the world is a major concern. In order to improve our understanding of pathogen interactions in the environment, more focus should be placed on field-scale studies rather than the large number of laboratory-based studies on pathogen contamination [21]. Assessing pathogen contamination at the watershed-scale is expected to be aided by the creation of new models and the enhancement of current modeling techniques that are frequently employed to forecast the levels of water-borne pathogens. It is necessary to update and develop new models in light of the limited capacity of current models to forecast pathogen contamination in order to increase the accuracy of pathogen level predictions [33]. Combining expertise from several disciplines (such as hydrology, microbiology and ecology) can assist develop long-term plans to enhance water quality as well as improve our understanding of pollution levels and its sources [34]. The testing and rapid detection of pathogenic organisms is a crucial stage in the prevention and identification of problems to health, safety and well-being [21]. Pathogenic organism testing and rapid detection are critical steps in the prevention and detection of health, safety and welfare issues. Testing of fecal indicator microorganisms where humans get infected is common in the whole world. With the prospect of unavoidable population expansion and an influx of tourism to particular water bodies, testing will become necessary to regulate and prevent potential outbreaks of potentially infectious diseases [35]. Indicator organisms, also known as water-borne pathogen footprints, are widely used to assess the pathogen load in water resources. Monitoring the quantities of indicator organisms (such as *E. coli* and fecal coliforms) is a typical method of quantifying the potential pathogen burdens in environmental water bodies. For many years, scientists and public health officials have measured the amount of fecal coliforms and *E. coli* in water to determine its quality [36-39]. Additionally, identifying the sources of infections (e.g., excrement from humans, animals, or wildlife, or waterfowl droppings) is important since infectious diseases caused by pathogens are the leading cause of mortality worldwide and the third most common cause of death in the United States [40]. Numerous novel harmful infectious diseases have emerged in the last 20 years [41]. Anthropogenic changes, including the development of water resources, global warming and human-wild animal interactions, are mostly to blame for these [17,42-45]. To get rid of the biological contamination in drinking water, many methods including oxidation treatment, ultraviolet radiation, distillation, electrochemical filtration, biologically active carbon filtering and nanotechnology were used [46,47]. Water resources have been shown to contain some biological contamination, such as pathogenic microorganisms [47]. Biology is a significant factor in having access to clean drinking water. In regions with well-established, centralized water treatment systems [48,49]. The control of waterborne pathogenic bacteria is accomplished through the integration of well-established disinfection techniques, such as UV, ozonation and/or chemicals, with physical processes like screening and filtration, these methods demand a substantial amount of energy and resources [50,51]. The process of killing, eliminating, or deactivating pathogenic germs is called disinfection. Disinfection, however, can be broken down into multiple steps and only a high degree of disinfection is capable of completely getting rid of microbes [52]. In addition, chlorination is a method of disinfecting drinking water that necessitates the presence of residual free chlorine and chloramines in distribution systems in order to preserve water quality and stop the growth of harmful bacteria [53]. These disinfection agents, however, are costly, dangerous and difficult to apply in underdeveloped or isolated areas with inadequate infrastructure. As a result, there is a need for low-energy, long-term sustainable solutions that can provide potable water and are scalable with minimal energy, maintenance and material requirements [50]. The high prevalence of these diseases in poorer nations can be attributed to inadequate sanitation and limited access to clean water. The majority of the infections were spread to humans by the fecal-oral route and shared symptoms like fever, diarrhea and aches in the body and muscles [54]. Numerous disinfection techniques exist, each having advantages and disadvantages of their own. While some were inexpensive and simple to use, they weren't as efficient against microbes. Therefore, even when the water has already undergone disinfection, biological contamination may still happen [55]. Numerous pathogenic bacteria, such as Vibrio cholerae, *Escherichia coli*, Salmonella typhi and others, have been identified in water. These bacteria can lead to a range of water-borne illnesses, including cholera, typhoid, diarrhea and more [7,56].

CONCLUSIONS

One of the most basic need for living is water. The world's useable water resources make up about 0.3% of the total. In many areas, there are existing water shortages and over a billion people lack access to clean drinking water. One of the most significant signs that we should be extremely cautious and aware of our water supplies is the current state of affairs. The requirement for water rises along with the global population. However, water resources are depleting, becoming more contaminated, and being utilized subconsciously due to a variety of factors, particularly human activity. Therefore, it is crucial to identify biological contaminants quickly in order to stop a widespread spread, establish a security zone, and alert the public and medical professionals so that the proper preventative measures may be taken.

Water networks may include poisons or infections. Currently, counting bacteria is used to monitor biological contamination in water, and laboratory analysis can take more

than a day. To fully protect against exposure to aquatic pathogens, this is too slow. The existing methods are limited by their reliance on culture techniques, which determine the growth of a microorganism after an extended period of incubation or evaluate a metabolic endpoint. Furthermore, it might be difficult to distinguish between pathogenic and non-pathogenic bacteria without accurate identification, particularly when it comes to newly discovered biological pollutants. There are technologies that can shorten the measuring time and accurately identify infections. We must therefore use water resources cautiously and act quickly to take and execute essential measures. Over the next decades, one of the biggest worldwide challenges will be meeting the demand for fresh water. Just 2.5% of the water on Earth is fresh water. Moreover, only 10% of freshwater is said to be fit for human use, and only 0.77% of freshwater is considered accessible [57-60]. Recent advancements and emerging technologies in water disinfection are addressing challenges like energy efficiency, sustainability, and the removal of complex contaminants. Which includes; Advanced Oxidation Processes (AOPs), UV-C LED Disinfection, Nanotechnology in Membranes, Electrochemical Disinfection, AI-Driven Optimization, Energy-Efficient Desalination, Biological Treatment Innovations and Carbon-Based Purification. These improvements collectively signify a transition towards more sustainable, effective, and flexible water disinfection systems that tackle both conventional toxins and emergent difficulties in water treatment [61].

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